U.S. COAST GUARD

TESTING and DEVELOPMENT DIVISION

OFFICE OF ENGINEERING WASHINGTON, D.C.

REPORT

FIELD TESTING AND DEVELOPMENT CENTER

REPORT NO. 403

PROJECT J15-2/4-1

EVALUATION OF SIGMA V-97
SURFACE-PASSIVATED, PHOTOCONDUCTIVE CELLS

Releasable to Government
Agencies only

3 DEC 1964


U.S. COAST GUARD
FIELD TESTING AND DEVELOPMENT UNIT
INCHES
0 1 2 3 4 5 6

FIELD TESTING AND DEVELOPMENT CENTER

PROJECT J15-2/4-1

EVALUATION OF SIGMA V-97 SURFACE-PASSIVATED, PHOTOCONDUCTIVE CELLS

By

FIELD TESTING AND DEVELOPMENT CENTER
U. S. COAST GUARD YARD
Curtis Bay, Baltimore, Maryland 21226

Date: 3 DEC 1964

Submitted: ______________________
P. O. CHAPMAN, CDR, USCG
Commanding Officer, FT&DC

Date: DEC 11 1964

Approved: ______________________
C. E. McAULIFFE, CAPT, USCG
Chief, Testing and Development Division
Office of Engineering
Washington, D.C. 20226

Authority: This project was performed under the authority of Comdt(ETD) ltr J15-2/4-1 Ser 396 of 11 October 1963.

ABSTRACT

This report covers the comparison of surface-passivated and non-surface-passivated, CdS photoconductive cells for use as "sun relays" for solid state flashers. Both accelerated tests in a controlled humidity chamber and exposure tests were conducted.

The exposure tests revealed that the surface-passivated cells had a significantly longer life than the non-surface-passivated cells. The normal failure of a non-surface-passivated cell was to increase its resistance at a predetermined illuminance level while the failure of a surface-passivated cell was to decrease its resistance. The surface-passivated cell was not "fail safe" since it would not turn on the flasher until the ambient illuminance was much less than the predetermined level.

TABLE OF CONTENTS

1. INTRODUCTION:

The United States Coast Guard maintains a large number of lighted aids to maritime navigation which operate from battery power supplies. These lighted aids are commonly flashed on a coded characteristic for identification purposes and to conserve battery power. Battery power may also be conserved by extinguishing these aids during daylight hours when, because of the high ambient illuminance level, their lights cannot be seen.

Realizing this problem, the Coast Guard is equipping lighted aids with "sun relays" to extinguish them during daylight hours. When solid state flashers are used, the "sun relay" becomes a simple photoconductive cell whose resistance is a function of the ambient illuminance. The purpose of this project was to compare two types of photoconductive cells, one with and one without a passivated surface, for possible use as the "sun relays" with solid state flashers.

2. MATERIALS TESTED:

One-hundred Sigma V-97 surface-passivated photoconductive cells manufactured by Sigma Instruments, Inc., 170 Pearl St., South Braintree, Mass., and seventy RCA SQ-2507 photoconductive cells manufactured by the Radio Corporation of America, 30 Rockefeller Plaza, New York, N. Y. were procured for testing. Both types of cells employ cadmium sulfide as the active material. The cadimum sulfide surface of the Sigma cell has a protective coating applied and is termed "passivated" by the manufacturer. All 170 cells procured were specified to be hermetically sealed and to have a resistance of 1200 ohms at an illuminance of 50 foot-candles.

The Sigma cells were obtained at a unit cost of $3.40 and the RCA cells at a unit cost of $1.55. The photoconductive cells are shown in the Frontispiece, the RCA cell to the left of the Sigma cell. Both cells are 1-1/4 inches in diameter, 1/4 inches in height, have two 3/8-inch pins for electrical connections, and weigh about 1/4 ounces.

3. TESTS CONDUCTED:

The dark resistance and resistance at 50 foot-candles of sky light (no direct sunlight) were measured for each cell after various environmental tests. For the measurements at the 50-foot-candle illuminance level, a specially constructed box that allowed only sky light to reach the cells was used. Up to six photoconductive cells were mounted around and in the same plane as the photocell of a Weston Model 756 illumination meter. The illuminance on the plane of the cells was set to the 50-foot-candle level by use of a variable aperture that determined the area of the sky that each cell could "see". The resistance of each photoconductive cell was then measured with a comparison ohmmeter. The dark resistance was measured with the same comparison ohmmeter when the cells were in a dark environment.

The dark resistance and resistance at 50 foot-candles at an ambient temperature of 25°C was determined for each of the 170 cells tested. The effect of ambient temperature on the cells was determined by obtaining 50-foot-candle resistance measurements at temperatures of -20°C, 25°C, and 60°C.

Fifteen Sigma and fifteen RCA cells, each with their protective glass seals removed, were exposed to a dark environment at 50°C and 95-100 percent relative humidity for 144 hours. Their dark resistances and resistances at 50 foot-candles were measured at 48-hour intervals to determine what advantage the passivated surface of the Sigma cells offered over the ordinary surface of the RCA cells.

Eighty-five Sigma and fifty-five RCA cells, half of each type with their protective glass seals removed, were exposed to the weather in an unprotected location facing south. This exposure test began in January 1964 and was continued for nine months. The dark resistance and resistance at 50 foot-candles of each cell was measured at frequent enough intervals to provide meaningful data. These tests were meant to determine the reliability of these types of photoconductive cells in a realistic environment.

4. TEST RESULTS:

The initial resistances of the 170 photoconductive cells measured at 25°C were as follows:

a. Sigma V-97:

Dark resistance: all infinite with the exception of one cell whose resistance was 490K ohms.

Resistance at 50 foot-candles: mean of 100 cells, 1241 ohms; standard deviation, 196 ohms.

b. RCA SQ-2507:

Dark resistance: all infinite

Resistance at 50 foot-candles: mean of 70 cells, 1050 ohms; standard deviation, 138 ohms.

The variation in resistance of both types of cells with illuminance is shown in Figure 1 in Appendix A. These data are the mean of three average cells of each type as measured at 25°C. The 50-foot-candle resistance of both types of cells was found to increase as the ambient temperature increased. The rate of increase of resistance was about $1 \pm \frac{1}{2}$ ohm per °C for both types of cells tested.

The results of the elevated temperature (50°C) and humidity (95-100%) test of the cells with their glass seals removed are tabulated below. These data are given as the number of good cells remaining as a function of the exposure time. A failure was defined as a cell having a dark resistance of less than 500K ohms or a 50-foot-candle resistance that had changed by more than 20 percent from its initial value.

TIME	SIGMA V-97	RCA SQ-2507
0	15 (100%)	15 (100%)
48 hr.	3 (20%)	12 (80%)
96 hr.	3 (20%)	9 (60%)
144 hr.	2 (13%)	5 (33%)

After 48 hours, the active surface of one of the Sigma cells was cracked, causing its resistance to be infinite at all illuminance levels. After 96 hours, the dark resistance of another Sigma cell was reduced to 13K ohms. All other failures of both types of cells were a result of an increase in their 50-foot-candle resistances by more than 20 percent of their initial values.

The results of the exposure test of the cells with their glass seals removed are tabulated below. These data are also given as the number of good cells remaining as a function of the exposure time. A failure was defined in the manner described above.

TIME	SIGMA V-97	RCA SQ-2507
0	40 (100%)	28 (100%)
1 dy.	38 (95%)	25 (89%)
4 dy.	30 (75%)	3 (11%)
8 dy.	22 (55%)	0 (0%)
1 mo.	0 (0%)	

After one day, the active surface of one of the Sigma cells was cracked, causing its resistance to be infinite at all illuminance levels. All other failures of both types of cells were a result of an increase in their 50-foot-candle resistances by more than 20 percent of their initial values. The appearance of both types of cells before and after the one-month exposure are shown in Figure 2 in Appendix A.

The results of the exposure test of the cells with their glass seals intact are tabulated below. Again, these data are given as the number of good cells remaining as a function of exposure time. A failure was defined as above.

TIME	SIGMA V-97	RCA SQ-2507
0	45 (100%)	27 (100%)
1 mo.	36 (80%)	14 (52%)
2 mo.	32 (71%)	8 (30%)
3 mo.	31 (69%)	4 (15%)
4 mo.	30 (67%)	0 (0%)
6 mo.	26 (58%)	
7 mo.	24 (53%)	
9 mo.	21 (47%)	

After one month, three Sigma cells failed when their dark resistance dropped to about 200K ohms. After two months, the dark resistance of one RCA cell was reduced to 40K ohms. All other failures of the RCA cells were a result of an increase in their 50-foot-candle resistances by more than 20 percent of their initial values. However, all other failures of the Sigma cells were a result of a decrease in their 50-foot-candle resistances by more than 20 percent of their initial values. After the nine-month exposure test, the cells were in poor condition as shown in Figure 3 in Appendix A. Of the 27 RCA cells tested, 4 had cracked glass seals, 2 had condensation inside, and 12 had both cracked glass seals and condensation inside. However, only 8 of the 45 Sigma cells tested had condensation inside and none had cracked glass seals.

While making the above resistance measurements, it was observed that upon exposure to light, the RCA cells reached their equilibrium resistances immediately while the Sigma cells required about 10 seconds to stabilize at their steady-state values.

When breaking the glass seals prior to the above tests, it was noted that the glass seals of the RCA cells were thinner and more easily broken than those of the Sigma cells.

5. DISCUSSION:

Both the Sigma and RCA cells were specified to have a 50-foot-candle resistance of 1200 ohms. The mean of the Sigma cells (1241 Ω) was closer to the desired value than the mean of the RCA cells (1050 Ω). However, the standard deviation of the RCA cells was less (13% of the mean) than that of the Sigma cells (16% of the mean). When specifying the resistance at 50 foot-candles, the "light" source should be specified since the spectral response of photoconductive cells extends beyond the visible spectrum.

Temperature did not seem to have a great effect on the 50 foot-candle resistance of either type of cell. The 1 ohm per °C variation results in only a ± 3% change in the 50-foot-candle resistance over the -20°C to 60°C temperature range.

During the 144-hour elevated temperature and humidity test, the Sigma cells initially failed faster than the RCA cells. However, by the end of the test, the number of failures was about the same. This test did not yield any significant results.

The exposure test of the cells with their glass seals removed demonstrated that the Sigma cells were superior to the RCA cells. However, even though the Sigma's passivated surface slowed the deterioration of the active material, all cells had failed within one month.

The nine-month exposure test of the cells with their glass seals intact proved the superiority of the Sigma cells. About 50% of the Sigma cells were still good after nine months while all RCA cells had failed after four months of exposure. The majority of the RCA cells had cracked glass seals and condensation inside while only a few of the Sigma cells contained condensation.

All cells with their glass seals removed and the RCA cells with their glass seals intact, failed by their 50-foot-candle resistances increasing. This type of failure provides a "fail safe" feature when these cells are used with existing solid state flashers, i.e., a cell that failed will not turn the flasher off until the ambient illuminance is much greater than the predetermined level. However, when the Sigma cells with their glass seals intact failed, their 50-foot-candle resistance deceased. This type of failure is not "fail safe" since the low resistance will not turn the flasher on until the ambient illuminance is much less than the predetermined level.

The passivated surface of the Sigma cells caused them to be less active than the RCA cells. The Sigma cells were slower in responding to transient light and their exposed active surfaces less affected by heat, light, and moisture. However, for some unknown reason, the resistance of the protected, passivated surface decreased upon continued exposure to heat and light.

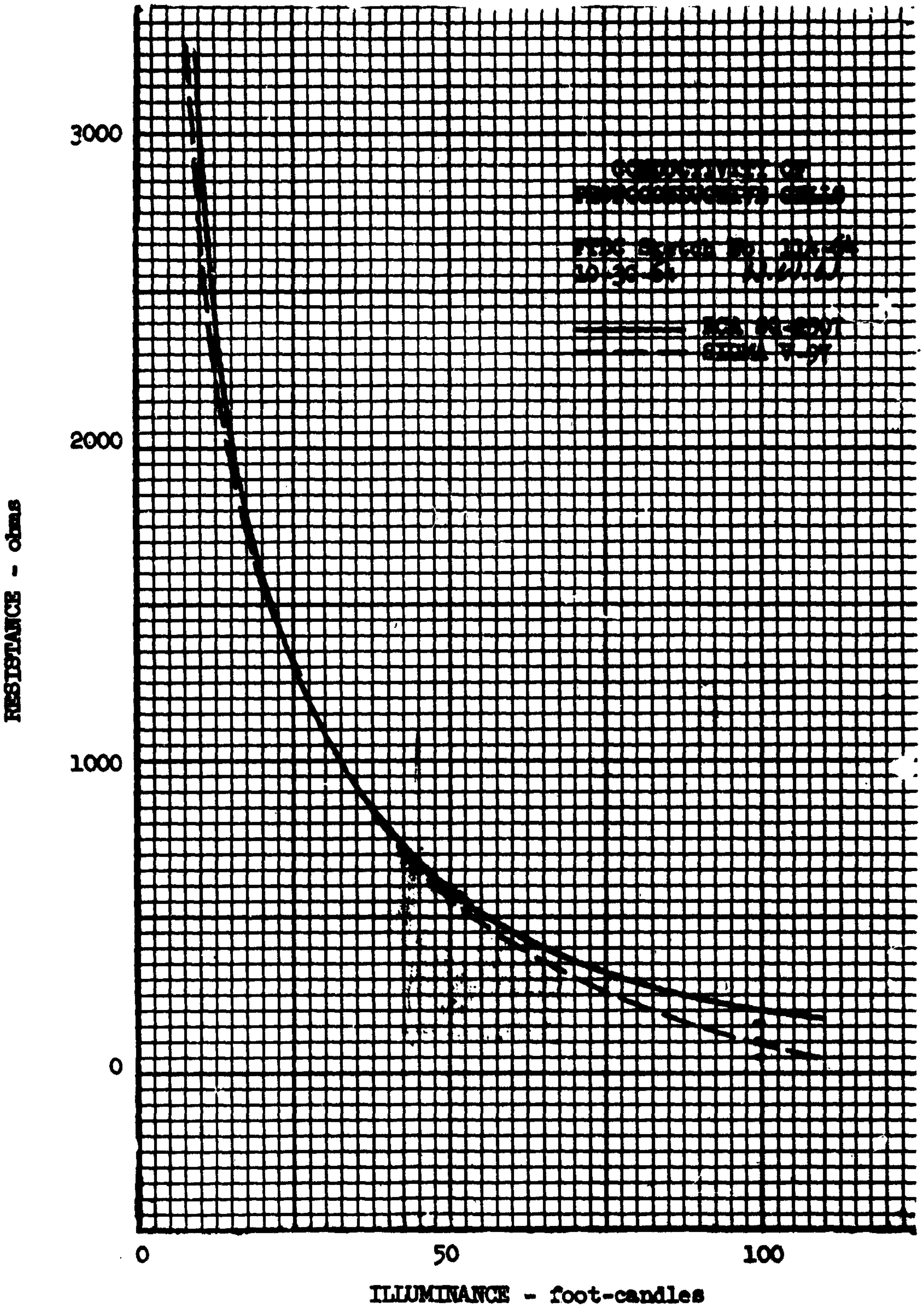
6. CONCLUSIONS:

The Sigma V-97 surface-passivated, photoconductive cell was superior to the RCA SQ-2507 photoconductive cell. The passivated surface of the Sigma cell was more resistant to the effects of heat, light, and moisture than the ordinary surface of the RCA cell. The glass seal of the Sigma cell was more effective than that of the RCA cell.

However, the Sigma cell did not offer the long term reliability required for use on an aid to maritime navigation. In addition, the normal failure of a Sigma cell is not "fail safe", i.e., the lighted aid would not be turned on until the ambient illuminance was much less than the predetermined level.

APPENDIX A

Figures



CONDUCTIVITY OF SIGMA V-97 AND RCA SQ-2507
PHOTOCONDUCTIVE CELLS

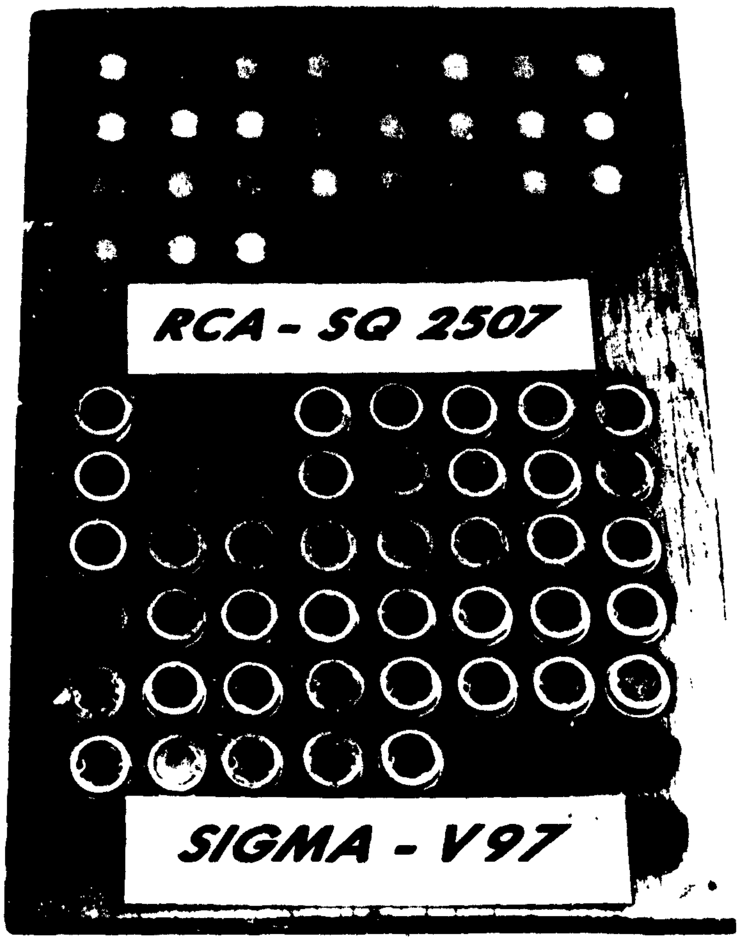
FIGURE 1

SIGMA V-97

RCA SQ-2507

PHOTOCONDUCTIVE CELLS BEFORE (LEFT) AND AFTER (RIGHT
A ONE-MONTH EXPOSURE WITH GLASS SEALS REMOVED.

FIGURE 2



PHOTOCONDUCTIVE CELLS WITH GLASS SEALS
INTACK AFTER A NINE-MONTH EXPOSURE.

FIGURE 3